

## Overview

### Timeline\*

- Start date: May 2019
- End date: Oct 2021
- Percent complete: ~70%

### Budget\*

- Total project funding: DOE: \$0.8 M
- Cost share: 0.21 M (21%)
- \* Phase II only

### Barriers

- Need high loading (>5mg-S/cm<sup>2</sup>) and low porosity (<50%) of sulfur cathode while still achieving high capacity to reach target energy density
- Need to solve polysulfide shuttle issue and improve cycle life

### Collaborations

- Pacific Northwest National Laboratory
- University of California, San Diego
- II-VI Incorporated
- Miltec UV International

## Relevance

### Impact

- Provide a handful of solutions to address the current issues of all major components of the Li-S battery in pouch-cell level.
- The innovative techniques and strategies can be further expanded and modified for other energy storage systems
- Small businesses or institutes could benefit from this complete solution, thus reducing the effort required for their own development work on the system.

### Objectives

- Sulfur cathode optimization
- Electrolyte optimization
- Pouch-format cell design, fabrication, and test protocol

## Milestones

Milestone	Type	Description	Time	Status
Demonstration of sulfur cathode	Technical	Demonstration of electrochemical performance of high loading and low porosity sulfur cathodes	Jan. 2020	Completed
Demonstration of novel electrode fabrication process	Technical	Demonstration of electrochemical performance of sulfur cathodes fabricated by new process	Jan. 2020	Completed
Determination of optimized electrolytes	Technical	Determination of the optimized electrolyte	April 2020	Completed
Demonstration of electrochemical performance	Technical	Demonstration of the electrochemical performances of the selected cathode with the optimized electrolyte	April 2020	Completed
Demonstration of final cell design	Go/No-go	Demonstration of pouch-format cell design capable of an energy density of ≥ 350 Wh/kg and cycle life of ≥ 200 cycles	April 2020	Completed
Final cell design and test	Technical	Demonstration of the optimized test protocols	Oct. 2021	In progress
Final cell design and test	Technical	Demonstration of pouch-format cells with an energy density of ≥ 500 Wh/kg and cycle life of ≥ 1000 cycles	Oct. 2021	In progress

## Approach

- Sulfur cathode optimization**
  - Screening of binder and additive for better adhesion
  - Surface treatment for better interface contact
  - Roll-to-roll scale up of slurry coating process
  - Cathode porosity control by optimization of calendar process
- Electrolyte optimization**
  - Develop new dual-phase electrolytes
- Pouch-format cell design, fabrication, and test protocol**
  - Implement of polysulfide trapping interlayer
  - Cell design with an internal developed software tool

## Summary

- Major milestones and deliveries were completed
- Successful scale up of C/S composite to Kg
- Developed roll-to-roll double sided continuous coating of S electrode
- Achieved flexible and cracking-free high loading S electrode with > 5mg-S/cm<sup>2</sup> and 70 wt. %S.
- Developed oxide/C coated separator with enhanced sulfur utilization while mitigating polysulfide shuttle. The coating process can be easily scaled-up for pouch cell fabrication.
- Developed proof-of-concept of new dual-phase electrolyte with improved cycle stability
- 5 patent, 3 journal publication, and 4 presentation in phase II

## Technical Accomplishments and Progress

### Continuous electrode fabrication and separator coating

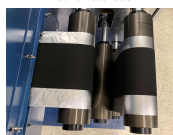
Corona discharge for Al surface treatment



Roll-to-roll coater for kg-scale coating



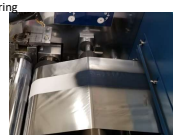
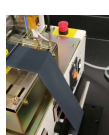
Double-sided sulfur cathode



Continuous separator coating with electric field control



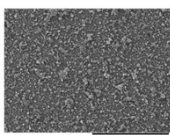
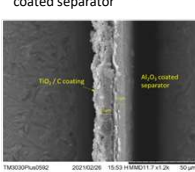
Roll-to-roll coating and calendaring



### Implement of polysulfide trapping layer to improve cyclability of S cathode

- The separator was coated with mixture of metal oxide/C layer with thickness of 10-16 μm
- Inhouse developed continuous coating process that can be easily scaled-up for pouch cell fabrication

Surface scan of coated separator



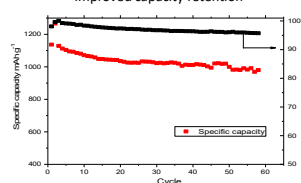
TiO<sub>2</sub>/C coated separator



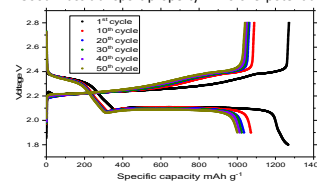
Cross section

### Implement of polysulfide trapping layer to improve cyclability of S cathode

- The coating can much improve the utilization of sulfur

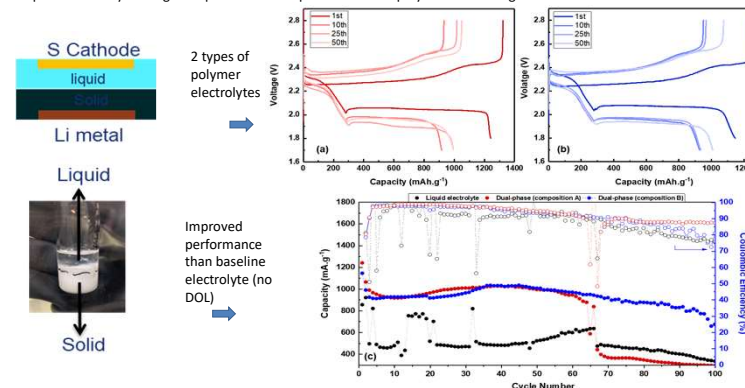


Good mass transport property --- no overpotential



### Dual-phase electrolytes: solid for anode protection and liquid for S cathode

- Dual-phase electrolyte design can provide lithium protection from polysulfide attacking



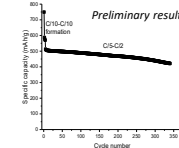
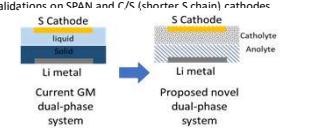
## Remaining challenges

- Demonstration of target energy density at pouch cell level. Need to further increase sulfur loading and reduce porosity of sulfur electrode to reach the target of 500 Wh/kg.
- Demonstration of target cycle life. Need to further improve lithium cycling efficiency/morphology to reach the cycle life target.

## Proposed Future Research

- A novel Dual-phase polymer electrolytes

- The new dual-phase design involve catholyte/ anolyte two polymer electrolyte components
- Validation on SPAN and C/S (shorter S chain) cathodes



Cathode: 6 mg/cm<sup>2</sup>  
Anode: 100 um Lithium  
Catholyte & Anolyte volume: 10 + 10 uL

- Demonstration of electrochemical performance
- Demonstration of final cell design and performance

\* Any proposed future work is subject to change based on funding levels